The application and impact of combined heat and power generating systems in the industry

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Abstract— In the last three decades, the major increase in fuel prices, talk of alternative fuels, increasing energy efficiency and reducing environmental pollution, the interest in using new technologies, including combined heat and power production (CHP) has increased. The results of the optimization of energy supply, improve production efficiency and reduce environmental pollutants resulting from energy production and energy supply sector, several optimization strategies have been proposed.

Keywords— Combined, gas turbines, piston engines, micro-turbines

I. INTRODUCTION

In conventional methods for supplying electricity and heat, electricity and heat by burning a fuel in boilers nationwide distribution network and heating equipment shall be provided by a separate production. In this method the Bell considerable energy law differently from the hot exhaust chimney, cooling towers, condensers, cooling of internal combustion engines and transmission and distribution losses in the electricity grid is wasted, most of this heat it is recyclable and can be used to provide thermal energy. Moreover, this method of centralized electricity production (power plants) and energy losses in practice.

In contrast to centralized systems, decentralized production methods independent of technology (CHP) is the combined production of electricity and heat simultaneously. In terms of thermodynamics, this method produces the same meaning as the usual electrical and thermal energy, is the primary energy source. The thermal waste heat energy recovery and heat generation can be achieved independently in various areas of industrial, commercial and residential buildings can be used. However, this technology generates electricity by local, independent and decentralized manner in which these two features together, the productive efficiency of electricity production significantly increased. will, as far as Europe, America and even in Asian countries such as Japan, policies and laws to encourage the use of combined heat and power production systems have imposed. The advantages of real-time production systems can move toward privatization and decentralized generation and independent electricity and heat, to prevent losses in the transmission and distribution grid, increasing energy efficiency and use, reduced fuel consumption and increased competition from electric power plant and reducing environmental pollutants and greenhouse gases, especially carbon dioxide a mention. These systems can tour most of the gas micro- turbine and piston engines; all equipped with heat recovery are pointed out.

Gas turbines, high reliability, high energy used in heating costs to produce a unit of output are relatively small investment. Gas turbines can operate continuously at low loads. Other disadvantages of these systems are limited in their capacity and ability needed to overhaul period is prolonged. The amount of heat generated by the engine piston engines burning fuel into mechanical motion into electrical power is produced using a generator. These engines also had advantages such as the possibility of working with low-pressure gas, a single act are several types of fuel.

Micro production systems, which are high-speed power turbine, compressor and generator, are. Micro conventional piston engines are smaller and their maintenance costs are also lower. Their reliability is high. Another advantage of this system easy to install, require less maintenance, small size, low noise and low emissions, but prices are relatively high.

The main production systems simultaneously:

Distributed generation systems produce electricity at the main analyzes, we included three systems are:

1 - Gas Turbine
2 - Piston engines
3 - Micro turbines

II. GAS TURBINE

Turbines for power generation were started. due to the use of gas turbines and air defense industry, much progress has been achieved in this field, so that the efficiency of gas turbines, steam turbines come over and use them to increase
have. Gas Turbine sizes ranging from a few hundred kilowatts to several hundred megawatts are available. These turbines, high-quality heat (high temperature) is produced which can be used for heating or industrial zone. Well appropriate choice for many industrial and commercial CHP is greater than 1 MW. Schema of a collection of gas turbine-based CHP is shown in Fig.

Figure 1 - The Gas Turbine

Gas turbines may be used in different ways:
1) The performance of a simple cycle gas turbine consists of a single generate electricity. The current status of the country's electricity industry is the same type of gas turbine is used only to generate electricity.
2) The performance of a CHP that a simple cycle gas turbine with an exchanger heat recovery, the addition of power generation thermal energy of the exhaust gases hot water or steam into and this is a situation that we study for future use we examined.
3) The performance of the combined cycle gas turbine exhaust temperature at which the vapor pressure is high and it will lead you in a steam turbine to produce more power is applied. Some combined cycle is removed from the steam which is used in industrial processes and sets the CHP.

Simple cycle gas turbines are used only for the production of hair rejection efficiency close to 35% (based on net heating value) is. Gases turbines are widely used in the amine plant to be used are peak periods.

In the early 1980s, efficiency and reliability for small gas turbines (1 to 40 MW) had values that were suitable for use in large industrial CHP systems. Gas turbines, heat, high-quality output is produced using systems in CHP efficiency of electrical (energy efficient) to 60 to 80 percent. Turbine gas emission equipment power generation is the amount of NOx in the exhaust gas they are very low. Due to the high efficiency and the use of natural gas as the primary fuel, the carbon dioxide CO2 in the gas turbine unit kWh produced than any other fossil fuel technologies are used.

A) Application
When the gas turbine is used to generate electricity, heat, and usually it is taken. Thus, the exhaust gases from the turbine are used to produce heat.
And also it can be used in industrial processes for heating or drying. The simple cycle gas turbine CHP with more small facilities less than 40 MW, are used.

Common examples of the use of gas turbines in CHP Commercial and Non-industrial complex, the university is a 5-MW simple cycle gas turbine in which approximately 8 MW of heat, steam (or hot water) pressure 150 to 400 psi in a heat recovery steam generator is produced and a central heating system to provide heat in the winter or the summer is shifted absorption chiller to cool the environment.

B) Description of Gas Turbine Technology
Steam turbine system based on thermodynamic cycles Brighton acts. This type of turbine exhaust gas temperature is high in small industries to approximately 800 to 900 degrees F. In large new power plants is 1100 degrees Fahrenheit. The temperature of the exhaust heat recovery steam generator may produce heat to generate electricity and also to be used in a steam turbine in combined cycle.

C) Types of gas turbines
Air derivative gas turbine turbines are one of the high thermal efficiency, but their prices are quite am too much. The maximum capacity of the turbines is usually 40 to 50 MW. With the development of advanced systems, turbines Air derivative large (greater than 40 MW) provide about 40% efficiency.

Industrial or frame gas turbines, gas turbines are two other types that are used only for power generation capacity of 250 megawatts and are available. These turbines are generally cheaper than Air derivative turbines; the distance between them is greater and higher than in the general maintenance of power generation is used, but their efficiencies and lower weight than other types of gas turbines. Large industrial turbines (greater than 100 MW) simple cycle efficiency of about 35% may occur.

In industries such as chemical, refining, paper, steel and major trading centers for the production of turbines used in combined heat and power consumption are used.

D) heat recovery
The gas turbine in the process of being economically dependent applications benefiting from the thermal energy contained in the exhaust gases

Which is typically 60 to 70 percent of the fuel energy input form. Common form of combined gas turbine and heat recovery steam generator is shown in Figure 2. Using motion recovery steam generator without combustion gas turbine CHP simplest form of steam and the steam pressure in psig 150 to about psig 1200 can produce.
E) Functional Specifications

F) Electrical efficiency

Turbines that are used to supply emergency power efficiency and low cost are low, whereas high annual capacity factor of wind turbines for applications that are used are high efficiency and price.

G) CHP system efficiency

Efficiency of the CHP system is a function of the amount of energy recovered from the exhaust system. The most important factors affecting the amount of energy available to produce steam, exhaust gas temperature and the temperature of the turbine exhaust stack heat recovery steam generator is. Turbine inlet temperature and pressure ratio, determine the exit temperature of the gas turbine's.

CHP systems are an essential part of the gas turbine, gas turbine, gearbox, electrical generator, inlet and outlet pipes, inlet air filtration systems, lubrication and cooling systems, light systems, standards and tools to reduce sound output, the price set base includes additional equipment such as compressor fuel, heat recovery systems, water purification systems and pollution control systems are not.

All these equipment are not necessary at all sites. Price of basic equipment and supplies, additional equipment, the total price is required. The total price includes the cost of facilities, equipment, materials and labor necessary for the installation, project management and financing during the construction period is 6 to 18 months.

In the table, the estimated total cost (cost of equipment and installation) to 5 prototype system is presented. These prices represent the average price of the ordinary. Prices offered in this section are for systems with pollution control, heat recovery steam generators without combustion, fuel density and feed water treatment plant includes a steam generator. Additional ignition system and the building are not considered.

H) The estimated total cost for gas turbine based CHP systems

<table>
<thead>
<tr>
<th>Equipment (thousands of dollars)</th>
<th>System 1</th>
<th>System 2</th>
<th>System 3</th>
<th>System 4</th>
<th>System 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine</td>
<td>675 $</td>
<td>1.200 $</td>
<td>4.100 $</td>
<td>11.500 $</td>
<td>15.100 $</td>
</tr>
<tr>
<td>Heat recovery steam generator</td>
<td>250 $</td>
<td>450 $</td>
<td>590 $</td>
<td>1.020 $</td>
<td>1.655 $</td>
</tr>
<tr>
<td>Water reclamation Systems</td>
<td>30 $</td>
<td>100 $</td>
<td>150 $</td>
<td>200 $</td>
<td>225 $</td>
</tr>
<tr>
<td>Electrical equipment</td>
<td>150 $</td>
<td>375 $</td>
<td>6250 $</td>
<td>990 $</td>
<td>1.500 $</td>
</tr>
<tr>
<td>Other equipment</td>
<td>145 $</td>
<td>315 $</td>
<td>575 $</td>
<td>1.150 $</td>
<td>1.875 $</td>
</tr>
<tr>
<td>Materials</td>
<td>144 $</td>
<td>346 $</td>
<td>689 $</td>
<td>1.490 $</td>
<td>2.054 $</td>
</tr>
<tr>
<td>Workman</td>
<td>348 $</td>
<td>879 $</td>
<td>1.752 $</td>
<td>3.715 $</td>
<td>4.723 $</td>
</tr>
<tr>
<td>The whole process</td>
<td>1.742 $</td>
<td>4.265 $</td>
<td>8.381 $</td>
<td>20.065 $</td>
<td>27.832 $</td>
</tr>
<tr>
<td>Project Management</td>
<td>125 $</td>
<td>304 $</td>
<td>594 $</td>
<td>1.486 $</td>
<td>2.105 $</td>
</tr>
<tr>
<td>Engineering</td>
<td>63 $</td>
<td>153 $</td>
<td>260 $</td>
<td>537 $</td>
<td>672 $</td>
</tr>
<tr>
<td>Determining Project Risk</td>
<td>87 $</td>
<td>215 $</td>
<td>419 $</td>
<td>1.005 $</td>
<td>1.392 $</td>
</tr>
<tr>
<td>Project Financing</td>
<td>129 $</td>
<td>316 $</td>
<td>618 $</td>
<td>1.483 $</td>
<td>2.048 $</td>
</tr>
<tr>
<td>Price of system</td>
<td>2.146 $</td>
<td>4.653 $</td>
<td>9.572 $</td>
<td>24.576 $</td>
<td>33.349 $</td>
</tr>
<tr>
<td>Real power turbine (kW)</td>
<td>1.210 $</td>
<td>5.200 $</td>
<td>10.600 $</td>
<td>28.600 $</td>
<td>43.400 $</td>
</tr>
<tr>
<td>Total price per unit of net kilowatt</td>
<td>1.781 $</td>
<td>1.010 $</td>
<td>969 $</td>
<td>859 $</td>
<td>785 $</td>
</tr>
</tbody>
</table>

1) Details of the estimated cost of the system installed on the land price model are selected. Prices may vary widely, and the site requirements and needs, price changes are related to regional and local environmental requirements.

2) Risks that they pose a risk in the project design, construction and maintenance are. It is the conceptual design and technical risk, the risk of making the change in prices, delayed projects, poor management and execution may be inappropriate and improper maintenance also influence risk.

Prices, according to an American research institution accredited by industrial group based Nexus quotations from several companies in 2001, is a famous American. However, to implement this system in the country, especially in the current price, for example, European and Russian can be so much more than fifty percent, depending on the equipment to be reduced further.

I) Maintenance

It has to be done periodically inspected every 4,000 hours of turbine vibration is not excessive. About 25,000 to 50,000 hours between overhauls Gas Turbine and during their inspection and full restoration of all components in order to achieve the performance standards or current (updated) takes place.

J) Variation of fuel

Most combustion gas turbines used in power generation using natural gas is designed. Heating value gaseous fuels used in gas turbines to give you 900 to 1100 standard cubic feet of natural gas is included. Clean liquid fuels suitable for use in gas turbines.

Many gas turbines can be used in both liquid and gaseous fuels there. When using gaseous and liquid fuels exist.

Combustion chamber pressure, gas turbines from 75 to 350
psig is pressure natural gas pipeline always much higher, but when measured at the entrance to the city, passing through the distribution system and measuring for delivery to the consumer is reduced.

 Depending POSITION gas distribution system of the gas turbine, gas compressor may be needed to fuel pressure due to the combustion system and turbine flow controller to adjust. Price of compressor increases the total price is set.

**K) the Accessibility**

Gas turbines by imported or assembled in the country are available. Now the factory is engaged in the manufacture and assembly of a gas turbine. But Iran cannot be made small turbines must be entered. In addition, European countries, Russia, high technology and are the cheapest in this area. The manufacturer of this equipment is shown in the Appendix to name a few.

### III. PISTON ENGINES

If reciprocating internal combustion engines technologies are known today. In North America each year more than 35 million units of engines for use in power generation and power cars, trucks, construction and mining equipment, etc., are produced propellant submarine. Efficiency motors to produce a wide variety of living could meet the needs of the market, including network power, emergency power generation and combined heat and power will be available. Piston engines can be used to produce output capacity of more than 7 kW to several MW. Schematic of piston engines used in CHP system is shown in Fig.

#### A) Application

Piston engines used for power generation in the provision of auxiliary load, peak load, strengthen the network or producing combined heat and power applications that require hot water or low pressure steam absorption chillers, they are. When these engines are used for cooling, heat output piston engine can be used in a single-stage absorption chiller. 50 kW to 8000 kW size limit of piston engines for commercial applications and is suitable for small offices and industrial units.

#### B) Description of the piston engine

Otto cycle and diesel cycle main mechanical components are similar. Both use a cylindrical combustion element of the piston during the move. The linear motion of the piston to urge the piston to rotational lag is bound to change.

According engine crankshaft speed (rpm) duty cycle (two-stroke or four-stroke) and the use or non-use of the turbocharger, they are divided. Many models of these vehicles and engines for power generation and heating and chiller are used.

The four-stroke diesel and spark ignition that is used for power generation, two of the following four steps are completed cycle power generation:

1) Suction: Suction air (diesel) or fuel-air mixture (spark ignition) into the cylinder
2) Density: compressed air or air-fuel mixture in the cylinder
3) Power: Building acceleration in the expansion of hot gases and high pressure piston
4) Discharge of combustion products exiting the outlet chamber cylinder

#### C) Performance characteristics
Table Combined Heat and Power Production System Performance characteristics of natural gas fuel for spark ignition engines ranging from 100 kW to 5 MW of use are provided. The area that most CHP engine work and is included in the applicable market. Heat rates and efficiencies are set according to data producers and industrial applications.

amount of energy available for useful thermal energy produced per unit of output decreases as the temperature is increased CHP system. Simultaneous production of electricity and heat in piston engines

1) Specification for gas engines are commercial in 2005.
2) Due to the rapid advances in information technology yields may be increased and the average efficiency is shown.

D) Return
Piston engines and electrical efficiency of 45% to 25% among commercial drivers are the most efficient. The lower limit of the range is the efficiency of smaller engines that require pollution control equipment.

E) Cost of investment
Overall system cost over $ 500 to 1500 kW is installed. It should be noted that adding additional equipment such as flue suffocating sound or noise insulation around the engine isolation as prices increase.

F) Storage
The engine maintenance includes checking and setting up a periodic timely replacement of engine oil, refrigerant and candles in every 2000 - 5000 hours. Considering the price maintenance overhauls usually 018/0 to 009/0 of dollars per kWh is working.

G) Thermal energy production
Heat can be recovered in piston engines from four sources: exhaust gases, the water used for cooling the engine oil and cooling water used for cooling the turbocharger. But the hot gas contains only half the energy output of the engine is a heat engine. In some cases industrial CHP applications directly to dry flue gas (Process drying) are used. Usually, hot water and steam CHP systems with piston engines for use in the process, environmental heating, hot water heating and absorption chillers are appropriate.

The most common methods of heat recovery system motor closed- cycle cooling as shown in the following. The engine cooling system for forced flow heat exchanger is used as a refrigerant.

Figure 4 heat recovery in a closed system
The natural flow of a refrigerant in cooling systems boiling water that boils, the engine is cool. This type of cooling system is usually combined with heat recovery steam under pressure, is used for output.

H) CHP potential in piston engines
An economic analysis of piston engines (the power supply capacity is at least 50 kW to 8000 kW), depending on the amount of heat energy in the exhaust gas and exhaust systems, bilge see their work. This energy is typically 60 to 70 percent of the fuel energy input. More heat from the exhaust gases and the cooling crust is recycled and heat recovery from cooling and turbocharger oil is low. Recovered heat to produce hot water or low-pressure steam engine used in the production process or for space heating and water heating and absorption cooling are used.

Refrigerant temperature of the engine cooling to 30 percent of the input energy and the ability to produce hot water is 200 to 210 degrees Fahrenheit. Some engines, such as engine cooling system boiling or pressurized water-cooling it to 256 degrees Fahrenheit is the temperature of the shell acts. Hot gases from the engine exhaust temperature of 30 to 50 percent heat loss is included. Exhaust gas temperature is usually 850 to 1200 degrees Fahrenheit. With heat recovery, approximately 60% to 70% of fuel energy to produce electricity and useful thermal energy used.

3-9 - availability in
At least more than five representatives of the big manufacturers of this equipment is available. But because of the sanctions imposed by several manufacturers of these equipment’s are working in this field in our country, most of them run out of Caterpillar Inc. USA, Vienna, Austria. This engine is also thrive across the state assembly and production equipment, simultaneous recovery of the engine cannot be made yet. Just prepare some Iranian companies importing into the engine and the generator are coupled it is also out. It should be noted that the building does not recycle easily build a complex situation at the plants, such as Azar water or Arak’s Machine Manufacturing Company. List of companies producing equipment investment for these systems are given in the Appendix A is
is possible damage to the system or increase the project duration. However, that depends on the expansion of the company's heavy-duty diesel engines installed on experience in this regard.

IV. MICRO

Micro turbine power generators are small liquid or gaseous fuel burn and an electrical generator to rotate at a high speed turn. Micro turbine test was started in 1997 and commercialized in 2000, primarily serving the technology began. Unfortunately, this system has been used in Iran.

The range can be produced by existing and developing micro turbine, is from 30 to 500 kW, while conventional gas turbine power from 500 kW to 350 MW. Act like high speed micro gas turbines can only be used in power generation or combined cycle CHP are used.

Micro turbine, can work with a variety of fuels including natural gas, sour (high sulfur), and the same liquid fuels such as gasoline, oil and gas and the use of resources, recycling, waste gases that were previously released to the atmosphere, burn. The following figure shows a schematic of a micro CHP system are:

![Figure 5 - The micro turbine CHP systems](image)

**A) Application**

When using micro CHP as a secondary heat exchanger exit micro residual energy to prepare hot water transfers. Outlet temperature may occur in cases such as heating water, operating absorption chillers, heating medium, the amine can be used for process heat. Most often used to supply hot water and heating CHP environment. The simplest application of CHP hot water supply.

**B) Description of micro turbine technology**

In a micro turbine system, a radial compressor compresses the incoming air, the air using turbine exhaust gas temperature, the preheat is prator Rico. Exhaust air-fuel mixture in the combustion chamber prator Rico and the hot gas combustion, through the expansion turbine and the turbine power is expanding. Expansion turbine, compressor running in single-axis models, it also disables the generator. Uniaxial models typically operate at a speed of 60,000 rpm and above and variable power and high frequencies are produced. The first power rectifier, a DC current is then converted to alternating current with a frequency of 60 or 50 Hz is.

Micro turbine based on thermodynamic cycle gas turbine Brayton cycle is called the Great, act. In this cycle, atmospheric air, compressed, heated, and then expanded to produce their electricity.

**C) Performance characteristics**

Micro efficiency and power density can be calibrated based on efficiency, internal loss and efficiency are highly dependent on system components are different.

Electrical efficiencies assuming water heater with an efficiency of CHP useful thermal energy produced is 80 percent, is calculated. In order to calculate the effective efficiency electric water heater hypothetical total amount of fuel entering the fuel consumption is reduced. The table shows that increasing the capacity of the micro turbine electrical efficiency also increases.

1) Information Technology and producers have been published. Producers include:

80kW, Capstone Model 330-30 kW, IR Energy Systems 70LM-70kW (two-shaft), Bowman TG80-Turbec T100-100kW data are presented for temperatures of 59 degrees Fahrenheit.

2) The overall efficiency of CHP is the sum of net electrical power and hot water production for thermal needs divided by the total fuel log.

3) Information about at least the possibility of increasing returns are at present.

Micro turbine may work in part-time, in which case changing the flow rate and inlet temperature can be achieved on. It should be noted that the significant effect of environmental conditions on the output power and efficiency
are micro. One of the measures that may be used to improve the efficiency of micro - cooling the inlet air is . Equipment required for this procedure are not yet installed on existing micro , but it is expected that the methods used for cooling the air in large gas turbines used are G , also used in micro .

D) potential for CHP
The simplest combination of micro CHP in commercial sectors , industry encompasses the following :
- Thermal and electrical loads simultaneously
- Thermal energy in the form of hot water
- Use electrical heat demand ratios in the range of 5 /0 - 5/2
- With more than 3,000 hours working hours per year micro turbine exhaust is used to generate heat that can be used to directly heat exchanger preheating send it to the dryer or processes . This output is also used for preheating combustion air .

E) Pollutant emissions
The micro level of emissions is very low . Since the amount of micro pollutants by taking measures to limit the reach micro turbine need to use these systems are not in control of the combustion . The main micro pollutants nitrogen oxides (NOx) carbon monoxide and unburned hydrocarbons are . A small amount of sulfur dioxide is produced in their system . Micro turbine is designed so that full -time and part- time to produce the least amount of pollutant emission levels are increased .4-6
- availability in

Because the technology of the equipment is delivered to the U.S. and several European countries, yet affordable equipment available in the country yet. This system is known as a manufacturer specifications in Appendix A of Equipment Manufacturers is available for those interested.

V. CONCLUSION
As described in this paper , combined heat and power production systems performance due to their high efficiency and low maintenance cost and easy installation , many applications have on the combined cycle power plants .Much of the technology, the equipment is delivered to the U.S. and several European countries , the possibility of preparing it is not possible at present .

REFERENCES
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